ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2013;94:667-72

ORIGINAL ARTICLE

Effect of Durations of Wheelchair Tilt-in-Space and Recline on Skin Perfusion Over the Ischial Tuberosity in People With Spinal Cord Injury

Yih-Kuen Jan, PT, PhD,[a] Fuyuan Liao, PhD,[a] Maria A. Jones, PT, PhD,[b] Laura A. Rice, PhD, MPT, ATP,[a] Teresa Tisdell, OTR/L, MPH, ATP[c]

From the [a]Rehabilitation Research Laboratory, Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, Champaign, IL; [b]Department of Rehabilitation Sciences, University of Oklahoma Health Sciences Center, Oklahoma City, OK; and [c]NeuroResources Rehabilitation Specialists, Oklahoma City, OK.

Abstract

Objective: To compare the efficacy of various durations of wheelchair tilt-in-space and recline on enhancing skin perfusion over the ischial tuberosity in people with spinal cord injury (SCI).

Design: Repeated-measures, intervention and outcomes measure design.

Setting: University research laboratory.

Participants: Power wheelchair users with SCI (N=9).

Interventions: Three protocols of various durations (3min, 1min, and 0min) of wheelchair tilt-in-space and recline were randomly assigned to the participants. Each protocol consisted of a baseline 15-minute sitting, a duration of 0- to 3-minute reclined and tilted, a second 15-minute sitting, and a 5-minute recovery. The position at the baseline and the second sitting was no tilt/recline of the participant and at the reclined and tilted and recovery was at 35° tilt-in-space and 120° recline.

Main Outcome Measures: Skin perfusion response to tilt and recline was assessed by laser Doppler and was normalized to mean skin perfusion at the baseline sitting.

Results: The results showed that mean skin perfusion during recovery at the 3-minute duration was significantly higher than that at the 1-minute duration ($P<.017$) and mean skin perfusion was not significantly different between the 1-minute and 0-minute durations (not significant). Skin perfusion during the second sitting was significantly higher at the 3-minute duration than at the 1-minute and 0-minute durations ($P<.017$).

Conclusions: Our findings suggest that performing the 3-minute duration of wheelchair tilt-in-space and recline is more effective than the 1-minute duration in enhancing skin perfusion of weight-bearing soft tissues.

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Pressure ulcers are among the most common secondary complications after spinal cord injury (SCI).[1] Despite the establishment of clinical guidelines and the progress of support surface technology,[2-4] the incidence of pressure ulcers in people with SCI remains high and relatively unchanged in the past 30 years (ie, ranged from 20%−35%).[1,5] The need to address this significant clinical problem has been pointed out by the Department of Veterans Affairs Quality Enhancement Research Initiative for Spinal Cord Injury.[6]

Various interventions have been recommended for the prevention of sitting-induced pressure ulcers in people with SCI, including pressure redistribution cushions, pressure-relieving activities (eg, push-up and lean forward), and wheelchair tilt-in-space and recline.[7] Wheelchair tilt-in-space and recline are especially suitable for people with tetraplegia who cannot perform pressure-relieving activities by themselves.[8] Both wheelchair tilt-in-space and recline provide relief from sitting-induced pressure

Supported by the National Institutes of Health (grant no. R03HD060751).

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

0003-9993/13/$36 - see front matter © 2013 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2012.11.019

while tilt-in-space works best for users with high muscle tone and orthopedic limitations and recline works best for users who require a full weight shift.[9] Several studies have demonstrated the effect of tilt-in-space and recline angles on seating interface pressure and skin perfusion in wheelchair users.[10-13] However, the current literature does not provide specific recommendations on the selection of wheelchair tilt-in-space and recline duration factor on reducing soft-tissue ischemia.[12,14] The knowledge gap may limit the benefit associated with using wheelchair tilt-in-space and recline on reducing the risk of pressure ulcers.

Clinically, bed-ridden patients are usually repositioned every 2 hours and wheelchair users are recommended to perform pressure-relieving activities every 15 to 30 minutes for 30 seconds.[7,15] However, assessing wheelchair push-ups and lean forwards on the recovery of skin perfusion showed that up to 42 to 300 seconds were needed.[16,17] If a pressure-relieving activity is not adequate to allow an increase in blood flow to ischemic tissues, the intervention may not benefit wheelchair users for preventing pressure ulcers.[12] In the literature, there are several studies investigating the effect of wheelchair tilt-in-space and recline angles on seating interface pressure, but no research studies have been conducted to investigate the effect of the durations of tilt-in-space and recline on reducing soft-tissue ischemia.[8,11,12]

Skin perfusion may be a good candidate to determine the efficacy of various durations of tilt-in-space and recline on reducing soft-tissue ischemia and risk of skin pressure ulcers.[12] A major benefit associated with periodically performing pressure redistribution activities is to allow for a reactive hyperemic response to restore blood supply to the ischemic tissues.[12,18] Reactive hyperemia is a local blood flow regulatory mechanism and remains functioning even after SCI. Reactive hyperemia occurs after occlusion of blood vessels; for a total relief after the occlusion, blood flow may increase several folds as compared with the baseline level; and for a partial relief, blood flow may not increase beyond the baseline level.[19,20] When performing wheelchair push-ups for pressure relieving in people with paraplegia, a full reactive hyperemic response may occur because of fully unloaded weight-bearing soft tissues. When performing wheelchair tilt-in-space and recline for pressure redistribution in people with tetraplegia, a partial reactive hyperemic response may occur because of partially unloaded weight-bearing soft tissues. By examining reactive hyperemic response to various durations of wheelchair tilt-in-space and recline, a guideline of the duration factor of performing wheelchair tilt-in-space and recline may be determined.

Our long-term goal is to develop clinical guidelines of wheelchair tilt-in-space and recline for preventing sitting-induced pressure ulcers in people with SCI. We have designed a series of studies to investigate the effects of various settings of wheelchair tilt-in-space and recline on skin and muscle perfusion. In our previous study,[12] we studied the effects of various angles of tilt-in-space and recline on skin perfusion and found that tilt-in-space should be at least 35° for enhancing skin perfusion over the ischial tuberosity when combined with 100° recline in people with SCI. In this study, we continue our effort to study the influences of the duration of tilt-in-space and recline on skin perfusion in people with SCI. We hypothesized that (1) skin perfusion during recovery is higher when wheelchair users with SCI perform tilt-in-space and recline at the 3-minute duration compared with the 1-minute and 0-minute durations, and skin perfusion does not show a significant difference between the 1-minute and 0-minute durations, and (2) skin perfusion during upright sitting after performing tilt-in-space and recline is higher at the 3-minute duration than at the 1-minute and 0-minute durations.

List of abbreviations:

ASIA	**American Spinal Injury Association**
LDF	**laser Doppler flowmetry**
NS	**not significant**
SCI	**spinal cord injury**

Methods

A repeated-measures, intervention and outcomes measure research design was used in this study.

Participants

We recruited 9 wheelchair users with SCI into this study. The participants were recruited from a local rehabilitation hospital. The inclusion criteria included traumatic SCI at the level between C4 and T5, at least 6 months after spinal injury, use of a power wheelchair as a primary means of mobility, and wheelchair seat width of .43 meters (17in) to .53 meters (21in). The exclusion criteria included cardio-respiratory diseases or other diseases that may significantly affect cardiovascular function, diagnosed skeletal deformities (scoliosis, pelvic obliquity, or hip and knee contracture), body mass index over 30kg/m^2, or active pressure ulcers. All participants gave informed consent to this study approved by an institutional review board. The demographic data of participants were as follows (values are mean ± SD): age 38.0±13.0 years, body mass index 24.5±2.3kg/m^2, 8 men and 1 woman, and duration of injury 6.0±5.9 years. One participant had sensory complete injury (American Spinal Injury Association [ASIA] grade A), 1 participant had motor complete injury (ASIA grade B), and 7 participants had incomplete injury (ASIA grade C).

Apparatus

Laser Doppler flowmetry (LDF)[a] and probe[a] were used to measure skin perfusion over the right ischial tuberosity in response to changes in durations of wheelchair tilt-in-space and recline.[12] LDF provides noninvasive, real-time measurement of skin perfusion at a depth of about 1 millimeter.[3] Skin perfusion was sampled at 32Hz for additional off-line analysis. A power wheelchair[b] with tilt-in-space and recline functions was used in this study. Seat width of the wheelchair was .48 meters (19in). A high-density foam cushion[b] was used in this study. The wheelchair tilt-in-space was defined as a change in person's orientation in space while maintaining the seat-to-back angle. The wheelchair recline was defined as a change in seat-to-back angle. The detailed configurations of wheelchair tilt-in-space and recline are provided in our previous study.[12] Two angle gauges[c] were used to measure the angles of wheelchair tilt-in-space and recline.

Wheelchair tilt-in-space and recline protocol

We selected commonly used time parameters by wheelchair users, including durations at 3 minutes, 1 minute, and 0 minutes for a total of 3 protocols.[15,21-23] The duration of wheelchair tilt-in-space and recline was defined as the time spent on the tilted and reclined

Table 1 A repeated-measure design of the efficacy of durations of wheelchair tilt-in-space and recline on skin perfusion*

Protocol	Ischemia Period (Baseline 15-min Sitting)	Tilted and Reclined Period	Ischemia Period (Second 15-min Sitting)	Recovery Period	Total Time
3-min duration protocol	15-min sitting at no tilt/recline	3min at 35° tilt and 120° recline	15-min sitting at no tilt/recline	5min at 35° tilt and 120° recline	38min
1-min duration protocol	15-min sitting at no tilt/recline	1min at 35° tilt and 120° recline	15-min sitting at no tilt/recline	5min at 35° tilt and 120° recline	36min
0-min duration protocol	15-min sitting at no tilt/recline	0min	15-min sitting at no tilt/recline	5min at 35° tilt and 120° recline	35min

* Three protocols consist of 3 durations (3min, 1min, and 0min) of wheelchair tilt-in-space and recline randomly assigned to the participants. A 5-min wash-out period was allowed between each protocol. Dependent variables are mean and peak skin perfusion over the ischial tuberosity.

position. Each protocol consisted of a 15-minute baseline sitting, a duration of 0- to 3-minute reclined and tilted, a 15-minute second sitting, and a 5-minute recovery. The baseline and second sitting position was no tilt/recline of the participant, and the reclined and tilted and recovery position was 35° tilt-in-space and 120° recline in this study. We chose the 15-minute sitting and the 1-minute duration because of clinically recommended settings of every 15 minutes for 30 seconds.[15,21-23] We added 30 seconds for a total of 1-minute duration to count the time needed to adjust wheelchair tilt-in-space and recline angles.[12] We chose the 3-minute duration to examine whether a longer duration than the clinically recommended 30 to 60 seconds would be more effective in reducing skin ischemia of weight-bearing tissues. The zero duration (continuous sitting with tilt and recline) served as the control for comparing the efficacy of various durations of tilt-in-space and recline in reducing ischemia. The selection of 35° tilt-in-space and 120° recline was based on our previous study that such angles are more effective in reducing skin ischemia.[12] Detailed descriptions of the 3 protocols are provided in table 1. The order of the testing conditions was randomly assigned to the participants.[24] A wash-out period was 5 minutes at 35° tilt-in-space and 120° recline between 2 protocols.[12] In this study, we did not have recline-only or tilt-in-space-only protocol because a combination of tilt-in-space and recline has been shown to be superior to the sole use of either wheelchair tilt-in-space or recline.[25,26]

Procedure

Room temperature was maintained at 23°C±2°C. Participants were kept in the laboratory for at least 30 minutes to accommodate the room temperature. This step allowed us to minimize the influences of skin temperature on skin perfusion.[27] During the acclimation period, participants with SCI were asked to empty their bladders. The participant was transferred to a mat table to tape the LDF probe onto the skin over the right ischial tuberosity. Then, he/she was transferred to the test power wheelchair. Regarding the procedure of applying an LDF probe, a participant was positioned in the side-lying posture, with hips and knees flexed at 90°. The tester then palpated the right ischial tuberosity to place the probe. The purpose was to minimize the displacement of the probe when the participant was transferred back to the wheelchair. Then, a correct location of the LDF probe on the skin over the ischial tuberosity was examined by palpation. Before the testing, the participants sat at 35° tilt-in-space and 120° recline for a duration of 5 minutes. Skin perfusion over the right ischial tuberosity was continuously measured throughout the study. The same person performed the adjustment of wheelchair tilt-in-space and recline settings (duration and angle of performing wheelchair tilt-in-space and recline) in all experiments in this study. The range of acceptable angles was ±3° of the set angle. Each participant spent about 2 hours completing the experiment.

Statistical analysis

The independent variables included 3 durations (3min, 1min, and 0min) of wheelchair tilt-in-space and recline. The dependent variables of this study were mean skin perfusion and peak perfusion of reactive hyperemia.[28] Peak perfusion was defined as the maximal blood flow during a reactive hyperemic response. To minimize the influences of movement artifact on skin perfusion, we did not average the first 20 seconds of each condition when tilt-in-space and recline was performing. The rationale for selecting 20 seconds was based on our experiments because 20 seconds was needed to complete the adjustment of wheelchair tilt-in-space and recline angles (35° tilt-in-space and 120° recline). We normalized individual's skin perfusion response to his/her baseline sitting skin perfusion.[29,30] A 1-way analysis of variances with repeated-measures design was used to examine the efficacy of various durations of wheelchair tilt-in-space and recline on enhancing mean and peak skin perfusion. Post hoc analysis was implemented by paired *t* tests with Bonferroni corrections. All statistical tests were performed at an alpha level of .05. For repeated-measures comparisons, the significance level was adjusted to .017. All statistical analyses were analyzed by using SPSS 16.[d]

Results

During the recovery period, mean skin perfusion of 3 protocols showed a significant increase compared with mean skin perfusion of the baseline sitting period ($P<.05$). Normalized mean skin perfusion was significantly higher at the 3-minute duration (1.92±.28) than at the 1-minute duration (1.35±.05) ($P<.017$) but not at the 0-minute duration (1.57±.21) (not significant [NS]) (fig 1). Normalized mean skin perfusion was not significantly different between the 1-minute and 0-minute durations (NS) (see fig 1).

During the recovery period, normalized peak skin perfusion of the reactive hyperemic response of the 3 protocols did not show a significant difference (NS), while normalized peak skin perfusion showed a higher value in the 3-minute (4.1±1.1) and 0-minute (3.7±1.5) durations compared with the 1-minute (2.15±.15) duration (fig 2).

During the sitting period, normalized skin perfusion of the second 15-minute sitting was significantly higher at the 3-minute duration (1.15±.07) than at the 1-minute duration (.96±.06) ($P<.017$) and the

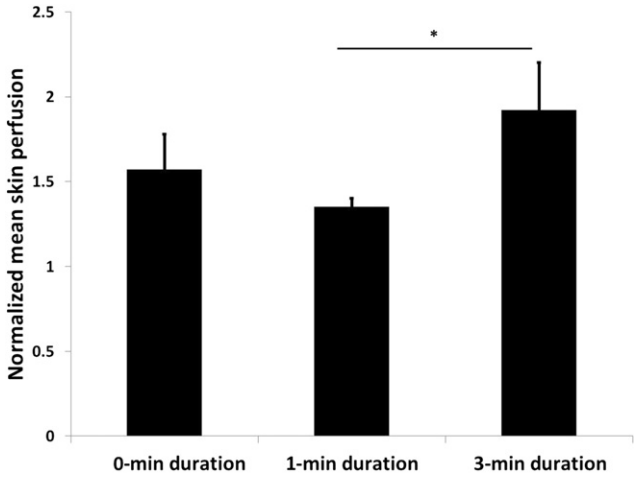

Fig 1 Comparison of normalized mean skin perfusion over the ischial tuberosity during the recovery period in response to various durations of wheelchair tilt-in-space and recline. The results show that normalized mean skin perfusion at the 3-min duration significantly increases compared with that at the 1-min duration ($P<.017$); mean skin perfusion is not significantly different between the 1-min and 0-min durations (NS). Mean skin perfusion during the recovery period at 35° tilt-in-space and 120° recline was normalized to the baseline sitting period at no tilt-in-space and recline. Data are shown as mean ± SE. * $P<.017$.

0-minute duration (.98±.03) ($P<.017$). Normalized skin perfusion was not significantly different between the 1-minute and 0-minute durations (NS) (fig 3).

Discussion

Our study demonstrated that the duration factor of wheelchair tilt-in-space and recline affected skin perfusion over the ischial tuberosity in wheelchair users with SCI. Our results indicated that skin perfusion during the recovery period at the 3-minute duration was significantly higher than at the 1-minute duration and was not significantly different between the 1-minute and 0-minute durations (see fig 1). Our study also showed that skin perfusion during the second sitting significantly increased after performing the 3-minute tilt-in-space and recline compared with the 1-minute tilt-in-space and recline (see fig 3). Along with our previous study,[12] we demonstrated that various angles and durations of wheelchair tilt-in-space and recline significantly affect the efficacy of enhancing skin perfusion in wheelchair users with SCI. Our method can be used to determine the proper settings of wheelchair tilt-in-space and recline for enhancing skin perfusion of the weight-bearing tissues.

We demonstrated that the 3-minute duration of tilt-in-space and recline may be more beneficial for the weight-bearing soft tissues compared with the l-minute duration during recovery. This finding indicates a significant issue that if the duration of tilt-in-space and recline is not adequate, ischemia caused by upright sitting may not be removed in wheelchair users with SCI.[31,32] This is consistent with previous research examining various pressure-relieving activities.[16,17] Makhsous et al[17] demonstrated that wheelchair push-ups for 30 seconds were not adequate for a full recovery of skin perfusion. Coggrave and Rose[16] also showed a similar conclusion that about 2 minutes of pressure relieving of the weight-bearing soft tissues was needed to restore tissue oxygen to the unloaded level. Our finding does not support the current clinical practice that the Consortium for Spinal Cord Medicine[7] published a clinical practice guideline recommending every 15 to 30 minutes for repositioning for 30 seconds. Our results indicate that skin perfusion during recovery was not significantly different between the 1-minute duration of tilt-in-space and recline and the continuous sitting condition (0-min duration). On the basis of our findings, we suggest that wheelchair users perform tilt-in-space and recline for a longer duration such as 3 minutes to minimize ischemia of weight-bearing

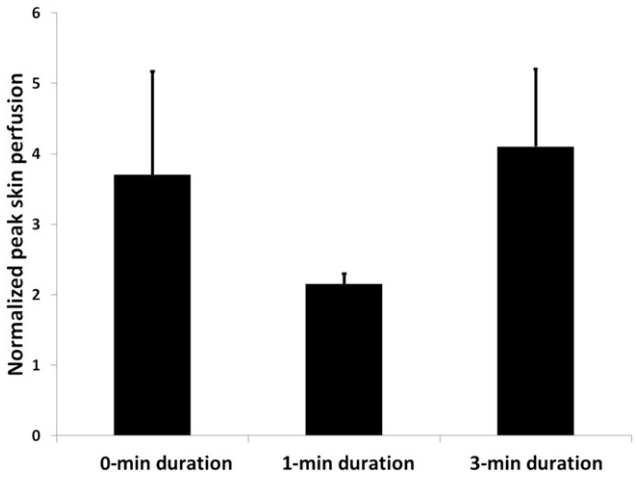

Fig 2 Comparison of peak skin perfusion over the ischial tuberosity during the recovery period in response to various durations of wheelchair tilt-in-space and recline. The results show that there is no significant difference in normalized peak skin perfusion among the 3 protocols. Peak skin perfusion during the recovery period at 35° tilt-in-space and 120° recline was normalized to the baseline sitting period at no tilt-in-space and recline. Data are shown as mean ± SE.

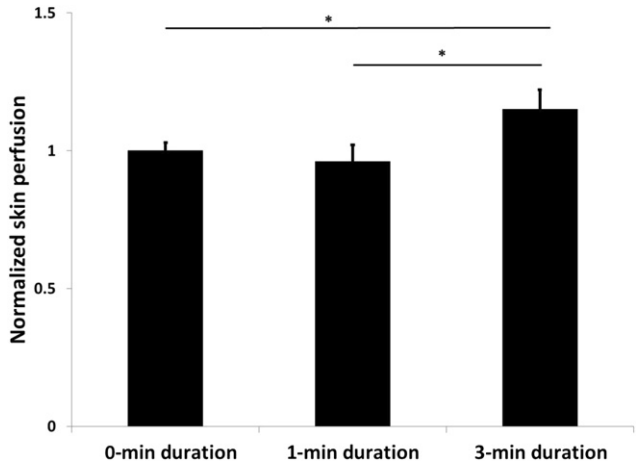

Fig 3 Comparison of normalized skin perfusion over the ischial tuberosity during the second 15-min sitting period at no tilt-in-space and recline after performing various durations of wheelchair tilt-in-space and recline at 35° tilt-in-space and 120° recline. The results show that normalized skin perfusion at the 3-min duration significantly increases compared with that at the 1-min and 0-min durations ($P<.017$); normalized skin perfusion is not significantly different between the 1-min and 0-min durations (NS). Skin perfusion during the second 15-min sitting period at no tilt-in-space and recline was normalized to the baseline 15-min sitting period at no tilt-in-space and recline. Data are shown as mean ± SE. * $P<.017$.

soft tissues. This statement warrants more research to validate its significance on reducing the risk of pressure ulcers.

The position at 35° tilt-in-space and 120° recline was used to assess the efficacy of various durations on skin perfusion in this study. The decision was based on our previous study[12] indicating that these angles can effectively increase skin perfusion during the recovery period. However, one needs to be aware that this finding can be applied only to angles of at least 35° tilt-in-space and 120° recline. Smaller angles of tilt-in-space and recline even with a duration of 3 minutes may not enhance skin perfusion. The clinicians should educate wheelchair users to perform large angles of tilt-in-space and recline (eg, greater than a combination of 35° tilt-in-space and 120° recline) to allow the development of reactive hyperemia to minimize ischemia of weight-bearing soft tissues. Also, the duration of tilted and reclined position is preferred to be 3 minutes rather than the clinically recommended 30 seconds to 1 minute based on our results. In real life, wheelchair users usually do not perform tilt-in-space and recline at these large angles and for such long durations.[21,22] This may partly contribute to a high incidence of pressure ulcers over the ischial tuberosity in people with SCI, especially people with tetraplegia.

Skin perfusion was used to evaluate the efficacy of various durations of wheelchair tilt-in-space and recline in reducing pressure ulcer risk in this study. We hypothesized that higher mean skin perfusion is beneficial for the weight-bearing soft tissues in terms of pressure ulcer prevention.[30,33] This is based on the ischemia theory that an inadequate supply of blood and oxygen to local cells and tissues causes soft-tissue ischemia, and beyond a threshold of ischemia, pressure ulcers will occur.[18,34,35] Aligned with this principle, pressure relieving associated with performing wheelchair tilt-in-space and recline may reduce the risk of pressure ulcers.[36,37] Although tissue ischemia may only be one of the contributing factors of pressure ulcers,[12] we believe that soft-tissue ischemia may be a better factor in assessing the efficacy of wheelchair tilt-in-space and recline in reducing the risk of pressure ulcers. This is particularly important in people with SCI as they lose the sympathetic outflow to the skin (peripheral autonomic dysfunction, dependent on the injury level) and heart (central autonomic dysfunction, injury level above T4-5), which causes microvascular dysfunction and a higher risk of pressure ulcers.[38,39] According to the current result, we support the use of noninvasive laser Doppler flowmetry to determine proper settings of wheelchair tilt-in-space and recline.[12]

Reactive hyperemia is the underlying physiological mechanism that contributes to an increase in skin perfusion during the tilted and reclined position.[12,30] Two theories have been proposed for the development of a reactive hyperemic response, including metabolic and myogenic theories.[30] Both metabolic and myogenic controls are a local regulatory response of skin microcirculation and still function in people with SCI but with an attenuated response.[12,18,40] Because metabolic and myogenic controls are mechanical stress—dependent regulations,[12,18,30]skin perfusion response thus can be modulated by the patterns of mechanical stresses caused by wheelchair tilt-in-space and recline. Theoretically, a proper configuration of angles and durations of wheelchair tilt-in-space and recline may be developed to utilize these local blood flow regulatory controls for enhancing skin perfusion, thus reducing the risk of pressure ulcers in people with SCI.

Study limitations

We only assessed skin perfusion for a short time rather than in real-life daily monitoring. Our findings may not be applied to determine the true efficacy of wheelchair tilt-in-space and recline in preventing pressure ulcers. Future studies may need to correlate the usage pattern of tilt-in-space and recline and the incidence of pressure ulcers to validate our finding. We recruited only 9 participants with SCI into this study. Concerning the variations in the level and severity of SCI, our results may not be extrapolated to all people with SCI. However, a homogeneous group of power wheelchair users was recruited for this study and the repeated-measures design was implemented in this study. Thus, the variations in spinal injury status may not confound our results.

Conclusions

Our study demonstrated that the duration of performing wheelchair tilt-in-space and recline affected skin perfusion of weight-bearing soft tissues over the ischial tuberosity. On the basis of our finding, we recommend that wheelchair users with SCI should perform tilt-in-space and recline for around 3 minutes to minimize ischemia of weight-bearing soft tissues and that a duration of 1 minute of wheelchair tilt-in-space and recline may not be effective in reducing ischemia.

Suppliers

a. PeriFlux System 5000 and LDF module 5010, and Probe PR415; Perimed, Inc, 44 W Lancaster Ave, Ste 220, Ardmore, PA 19003.
b. Power wheelchair C300 Corpus and Corpus seating system; Permobil, Inc, 6961 Eastgate Blvd, Lebanon, TN 37090.
c. Wixey digital angle gauge, Model WR300; www.wixey.com online store.
d. SPSS, Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Keywords

Laser-Doppler flowmetry; Pressure ulcer; Rehabilitation; Skin; Spinal cord injuries; Wheelchairs

Corresponding author

Yih-Kuen Jan, PT, PhD, Rehabilitation Research Laboratory, Dept of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, 1206 South Fourth St, MC-588, Champaign, IL 61820. *E-mail address:* yjan@uiuc.edu.

Acknowledgment

We thank the reviewers for their valuable comments on this manuscript. We also thank Permobil, Inc, for providing the power wheelchair for the experiments.

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